FOREIGN ECONOMIC DEVELOPMENT REPORT 11
JULY 1971

# Economics of Protein Improvement Programs in the Lower Income Countries

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ABSTRACT

This paper presents an overview of the world protein problems and some major economic considerations important to nutrition improvement programs. It discusses sources and uses of protein, the role of income, and benefit-cost dimensions of various strategies aimed at improving adequacy of protein consumption in lower income countries.

Two numbers dramatically depict the protein problem: (1) two-thirds of the world, the poor countries, command only half of the world's protein, mostly cereal protein, and (2) the billion people in developed countries use practically as much cereal for feed to produce animal protein as the 2 billion people in developing nations use directly as food.

Increasing incomes so people can command adequate protein has limited potential, says the author, so programs of supply--cereal breeding and fortification--take on increased urgency. He discusses such programs from the standpoint of consumers, government, private companies, and international assistance programs, considering costs, who pays, and who benefits--and by how much.

The author points to the need for nutrition research useful for measuring economic dimensions of protein programs. Failure to do this he says, "runs the risk that decision makers will bypass protein programs for others. And, no one will be able to show them that they have selected the wrong ones."

Key words: Protein, less developed countries, fortification, plant breeding, high protein varieties, nutrition, technical assistance.

# Economics of Protein Improvement Programs in the Lower Income Countries

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# I. INTRODUCTION 1/

Protein malnutrition is widespread in many of the lower income countries. This phenomenon has been recognized for many years. But, it has been only in recent years that there has been substantial interest in plant breeding and cereal fortification programs focused on this problem. This manuscript is an overview of the primary economic aspects of these programs. It discusses the sources and uses of protein, the role of income, and the benefit-cost dimensions of cereal breeding and fortification strategies aimed at improving the adequacy of protein consumption in the lower income countries.

Several factors account for increased interest in specific programs of breeding and fortification. One of the primary ones is the "Green Revolution." This phenomenon, largely confined to Asia, has given increased confidence in the potential payoffs from well-directed research.

Also, the new technology, in combination with improved weather, increased availability of inputs such as fertilizer, and improved agricultural policies, has meant increased cereal production. These increases have lessened the pressures that leaders felt in the crisis of the mid-1960's, thus permitting these men to now think in terms of the quality of the diets of their people as well as its quantity.

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1/This bulletin is a more extended version of a talk given at the AID Breeding and Fortification Workshop, Annapolis, Maryland, December 7, 1970. It includes much more material, particularly that of a statistical nature, than it was possible to include in the talk. As with the talk paper, it draws freely on a continual exchange of ideas with colleagues in FEDS, other USDA Agencies, and AID.

We can take satisfaction in this greater interest in protein problems. But, it would be a serious error to become overly optimistic as to how quickly these problems will be resolved. The quantity aspects of diets will continue to demand large allocations of resources in terms of scientific talent, national budgets, international assistance, policy, and management talent.

The theme of this paper is that protein problems must be considered in the context of overall development. Total resources are scarce and competition to use resources for activities other than improving the quality of diets will be intense. Thus, we must be concerned with the benefits and the costs of protein strategies for nutrition to be able to command a significant share of the resources.

## II. SOURCES AND USES OF PROTEIN

Two numbers dramatically depict the protein problem of the developing nations: (1) Two-thirds of the world, the poor countries, command only one-half of the world's protein, and most of that is cereal protein (Table 1), and (2) the billion people in the developed countries use practically as much cereals as feed to produce animal protein as the 2 billion people of developing countries use directly as food (Figure 1).

But, there are other important facts which help give a more complete picture of the sources and uses of protein. For example:

- In the early 1960's, total world protein consumption approximated 70 million tons.
- Half of the protein was supplied by cereals and almost 30 percent by animals.
- Two-thirds of protein consumption in lower income countries was cereal protein.
- Of this cereal protein, rice is the dominant supplier, especially in Asia where over 45 percent of the cereal protein has been derived from rice.
- In Latin America and Africa, corn and wheat have the dominant roles.
- In selected areas, pulses are important. For example, in India, pulses supplied more protein than did either wheat or rice.
- Also, in selected areas, millets and sorghums are important. For example, in Africa, they supplied more than either wheat, rice, or corn. In India, they supplied more than wheat or corn, but less than rice.

Table 1.--Total protein supplied by food groups, 1959-61 average.

| Subregion | Population 1959-61 | Wheat | Rice | Other cereals | Cereal total | Pulses & nuts | Animal | Other | Total protein |
|---|---|---|---|---|---|---|---|---|---|
| | Million | | | | Million tons | | | | |
| Diet adequate countries: 1/ | 1,089 | 8.6 | 1.1 | 2.8 | 12.4 | 1.9 | 15.4 | 3.2 | 33.0 |
| Diet deficit countries: | | | | | | | | | |
| Latin America | 84 | .3 | .1 | .3 | .7 | .2 | .6 | .2 | 1.7 |
| Africa | 242 | .6 | .2 | 1.9 | 2.8 | .7 | 1.0 | .9 | 5.3 |
| Communist Asia | 713 | 2.1 | 3.9 | 2.4 | 8.4 | 1.8 | .8 | 1.4 | 12.4 |
| India | 432 | 1.2 | 2.0 | 1.8 | 5.0 | 2.3 | 1.1 | .4 | 8.8 |
| Other Asia | 452 | 1.8 | 2.7 | .7 | 5.2 | 1.0 | 1.5 | .8 | 8.6 |
| Subtotal | 1,923 | 6.1 | 8.9 | 7.2 | 22.1 | 6.0 | 5.0 | 3.6 | 36.7 |
| Total World | 3,012 | 14.6 | 10.0 | 9.9 | 34.5 | 7.9 | 20.5 | 6.9 | 69.8 |

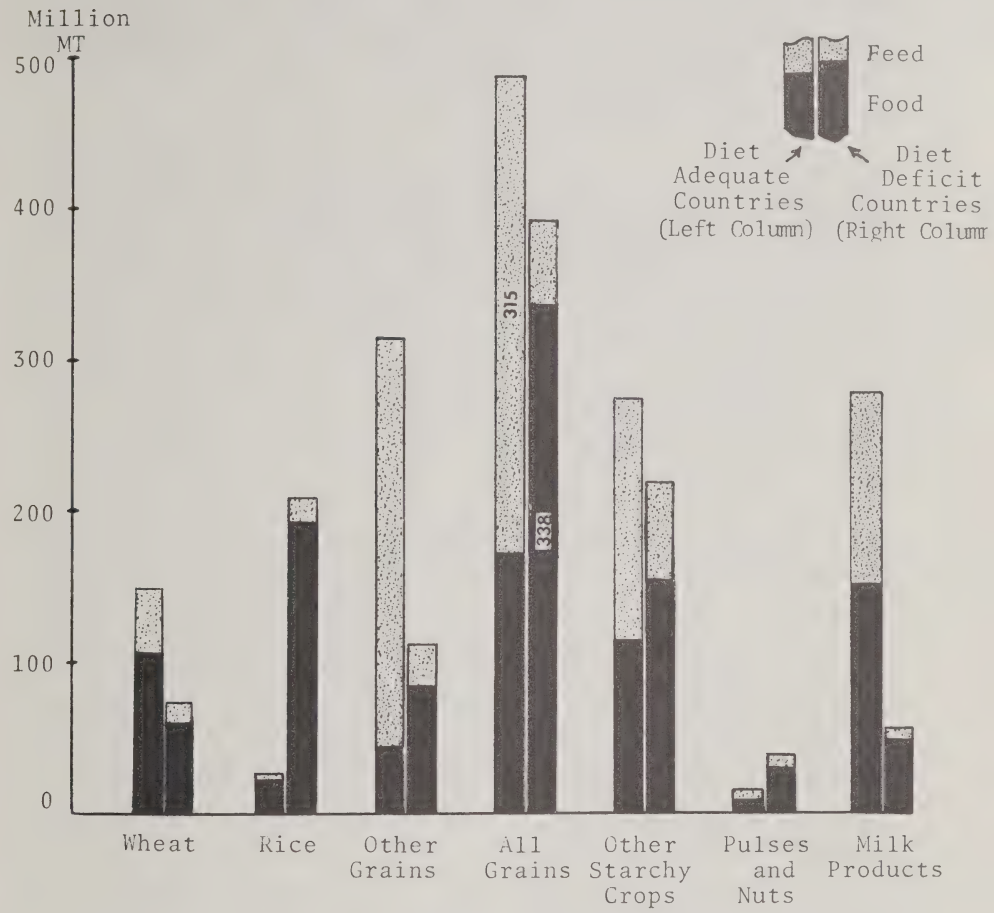
1/ Adequate diet countries include those normally grouped as developed countries plus Mexico, Brazil, Argentina, Uruguay, and Southern Africa. Other countries are grouped in diet deficit category.

Source: Derived from Quentin M. West, "The Quantitative Role of Cereals as Supplies of Dietary Protein," Protein: Enriched Cereal Foods for World Needs, Max Milner, Ed., American Association of Cereal Chemists, 1969.

Figure 1

UTILIZATION OF AGRICULTURAL PRODUCTS FOR FOOD AND FEED, 1959-61 AVERAGE.

Diet Adequate and Diet Deficit Countries1/




1/ Adequate diet countries indicate those normally grouped as developed countries plus Mexico, Brazil, Argentina, Uruguay, and Southern Africa. Other countries are grouped in diet deficit category.

Source: "The World Food Budget 1970," FAER No. 19, ERS, USDA, Table 36.

While the data of Table 1 are applicable to the 1959-61 period, the heavy dependence on cereals has continued since then. The relative importance of wheat and "other cereals," however, has probably increased in the lower income countries. Wheat and corn production in 1968 was more than 30 percent above the 1960-64 production. Rice production was but 14 percent higher. (Appendix Table 2)

The relative importance of pulses has declined since the 1950's, as pulse acreage has declined in many areas of the India subcontinent and the production of other cereals has increased. For example, in East Pakistan, pulse acreage and production have declined dramatically after reaching a peak in the early 1950's.1/ Production declined by one-fourth over a 13-year period at the same time that population was increasing at the rate of 40 percent every 10 years.

In India, pulse production dropped in the first half of the 1960's from the 25 to 30 kg. per capita range to around 20 kg. It then leveled off on a per capita basis. In comparison, per capita cereal production has regained the levels of the early 1960's after dipping sharply in the mid-1960's. It is important to note that the sharp increase in cereal production in recent years does not appear to have been associated with declines in per capita production of pulses (Appendix Figure 1).

In the developing countries as a whole, livestock are supplying an increasing amount of protein. But on a per capita basis, these supplies have generally declined over the years and are still extremely small in comparison to consumption levels in developed countries.

As pointed out above, the most striking contrasts are: (1) the heavy dependence of the developing countries on cereals for protein, as well as calories, and (2)

1/ E. Pakistan Bureau of Statistics, Statistical Digest of E. Pakistan (Dacca: East Pakistan Bureau of Statistics, No. 5, 1968).

the use of large amounts of cereals for livestock feed by the developed countries. For example, the developed countries used 315 million tons of cereals in non-food uses per year in 1959-61. The developing countries used only a trifle more as food. The people of India use less than 1 percent (.5 percent) of their available cereals as animal feed; Kenya uses 6 percent; the United States uses 80 percent.

The contrast with milk products is even more striking. The developed countries use over 125 million tons in non-food uses; the poor countries use but 50 million tons as food and less than 10 million tons in other uses. (Appendix Table 3)

Protein content of diets varies greatly among regions, nations, regions within countries, families, and among family members. This variability is a fundamental phenomenon which programs of plant breeding and cereal fortification must take into account. It argues for great flexibility in program design.

Among Regions and Nations

In terms of variability among regions, the Far East, at 50 grams per person per day, has the lowest per capita protein intake. In contrast, protein consumption in the Near East is 70 grams per person per day. The Far East also has the lowest proportion of its protein derived from animal products, only 16 percent in contrast to 54 percent for the developed countries as a whole and over 70 percent for the United States.1/

The African situation is a dramatic illustration of wide variation among subregions and nations. The Savannah regions of West Africa have protein consumption levels of close to 70 grams per person per day.

1/ Food and Agriculture Organization of the United Nations, Agricultural Commodities--Projections for 1975 and 1985, Volume II (FAO, 1967).

In comparison, in the Southwest Zone of West Africa, the protein intake approximates 43 grams, a level just slightly higher than the levels in the Congo and the Dominican Republic, the two countries included in the FAO Indicative World Plan (IWP) study with the lowest per capita protein consumptions.

Among Regions Within Countries

Brazil is often cited as a country with wide variations within its borders. Nutrition is no exception. Brazil has had a nutrient supply on a national basis significantly above acceptable standards. However, in the Northeast and urban centers of other areas such as the South, many diets are grossly inadequate. For example, some 75 percent of the people in the Northeast had caloric intakes below 2,450 per day in 1960. In the South it was 29 percent, but the incidence was heavily concentrated in urban areas; there, some 44 percent were below the 2,450 level in contrast to only 3 percent in rural areas.

Table 2--Brazil: Population with daily per capita protein intake below indicated levels, 1960.

| | Calories below 2,450 | | Protein below 55 grams | |
|---|---|---|---|---|
| | Northeast | South | Northeast | South |
| | Percent | | | |
| Total | 75 | 29 | 20 | 1 |
| Urban | 76 | 44 | 18 | 12 |
| Rural | 76 | 3 | 13 | 0 |

Source: Food Consumption in Brazil--1960, Center for Statistical and Econometric Studies, February 1969, Tables 1b and 2b.

In terms of protein, 20 percent of the people in the North consumed less than 55 grams; in the South it was one percent. But again in the South, urban families

had a significantly larger incidence of protein deficiencies than did rural families.

Obviously, the large proportion of the population in Northeast Brazil with low caloric intakes has significant implications for fortification programs in this area. For example, a program in this area would need to take into account the effect of low caloric intake on the potential impact of fortification programs.

Among and Within Families

East Pakistan is illustrative of variation among families. In urban areas, households with incomes of 0 to 99 rupees per month had per capita protein consumption averaging only 41 grams per day; and these low levels were associated with caloric intakes of only 1,550. Other urban groups within East Pakistan averaged 50 to 54 grams of protein per day. In rural areas they averaged over 70 grams.1/

Surveys show that, in many cases, families as a whole may have adquate diets, but children and females receive insufficient protein, both because their protein requirements are higher and because other members of the family, especially the father, traditionally have first claim on the available food.2/

1/ Public Health Service, Pakistan, Nutrition Survey of East Pakistan, March 1962—January 1964 (Washington, D.C.: U.S. Department of Health, Education, and Welfare, May 1966), Appendix Table II-II.

2/ George N. Foster, "Social Anthropology and Nutrition of the Pre-school Child," Pre-school Child Malnutrition (Washington, D.C.: National Academy of Sciences--National Research Council, 1966), p. 260.

## III. THE ROLE OF INCOME

The fundamental situation is that large numbers of people in the developing countries do not have the incomes to command the food which would give them adequate protein in their diets. This basic phenomenon overhangs all efforts to bring about nutrition improvements. And, this is the basic reason, barring a miracle, why nutrition improvement must be viewed as a long-term process.

The outlook for income growth is such that great dependence on staple foods will continue and, in turn, protein deficiencies will prevail for many years. Consumption surveys amply indicate that limited incomes will not permit commodities such as sugar, meats, oils, fruits, and vegetables to occupy a major role in the diets of a large segment of many populaces.

In comparisons among countries, the relationship between per capita income and per capita protein consumption is not as close as for animal protein and fat consumption. However, the influence of income on protein consumption is unmistakable, especially when one makes allowance for the effect of ecology, which influences the type of crops grown and, in turn, the adequacy of diets. (Appendix Figures 2, 3, and 4)

Perhaps the most prominent example of the ecological influence is in West Africa. The Savannah Zone, with incomes one half that of the Southern Zone, has protein intake of close to 70 grams per day. In the Southern Zone,it is 50 grams. Grains are prominent in the Savannah Zone. In the Southern Zone, there is great dependence on starchy roots. (Appendix Table 4)

These analyses are static in nature. Data showing changes in dietary patterns with changes in income over time would be preferable and, I hypothesize, would show a much closer relationship than do the variables plotted in Appendix Figures 2, 3, and 4.

Animal protein consumption has a much closer relationship to income than does total protein consumption (Appendix Figure 3). Another relationship, fat consumption and income, has received less attention but is also of great importance. Appendix Figure 4 suggests a very high income elasticity of demand for fats. This relationship has important implications. From an economic point of view, it means a need for increased fat and oil supplies as incomes increase. It also has indirect implications for protein consumption. First of all, fats and oils enhance the caloric intake and, therefore, are likely to be complementary to increased protein consumption. But the relationship means that fats and oils have a claim on increased incomes, thus leaving less for protein.

Consumption survey data dramatically indicate the influence of incomes on diets. With increases in income, the consumption of protective foods, livestock, sugar, fats, and oils increase; direct consumption of cereals and carbohydrate foods at first increases, declines, and then, at higher incomes, levels off substantially below the levels of consumption at very low incomes. Other food products are increasingly substituted. 1/

Influence of Income is Clear

The exact relationships vary from country to country. But the positive relation between increased income

1/ Food and Agriculture Organization of the United Nations, Agricultural Commodities--Projections for 1975 and 1985 (FAO, 1967), Volume 1, p. 38.

and increased food consumption and expenditures is clear, as shown by studies in the following countries:

Brazil - The same study which indicated the sharp contrast in dietary levels among regions of Brazil found that consumption levels of protein are roughly comparable for people in different regions of comparable income levels (Figure 2). The differences in calories are somewhat larger. But for both protein and calories, the data show a clear positive relationship between income levels and nutrient consumption levels.

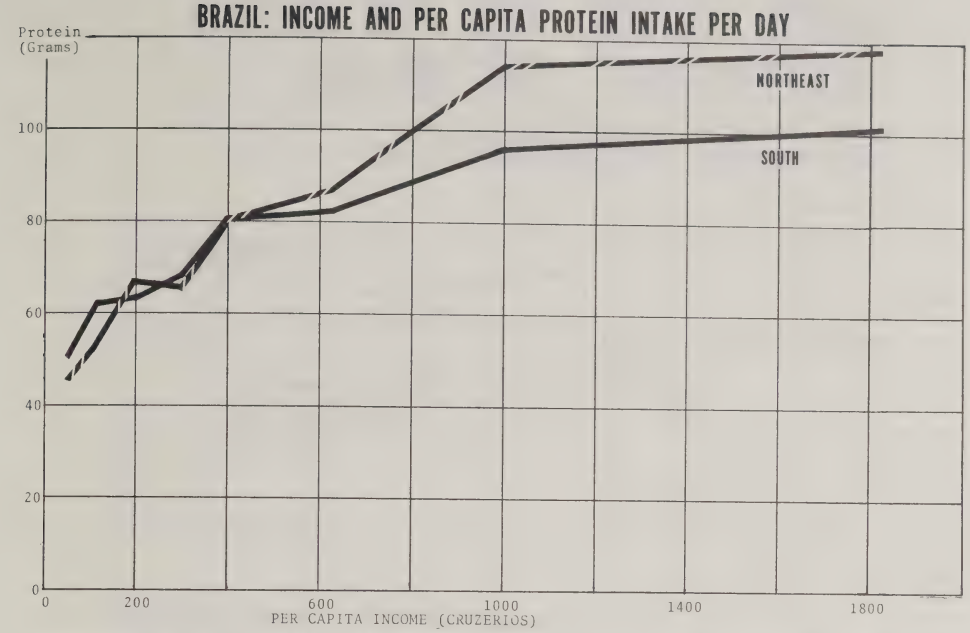
India - The five figures for India illustrate similar relationships between food consumption and income. The response of the demand for milk with income changes is especially impressive (Figure 3).

East Pakistan - The data for East Pakistan suggest a very dramatic difference between the diet of rural and urban families at corresponding income levels, as well as sharp differences between the diets of the lower income families and the diets of higher income families (Figure 4).

Increased incomes also stimulate changes in food consumption which have a deleterious effect on nutrition.

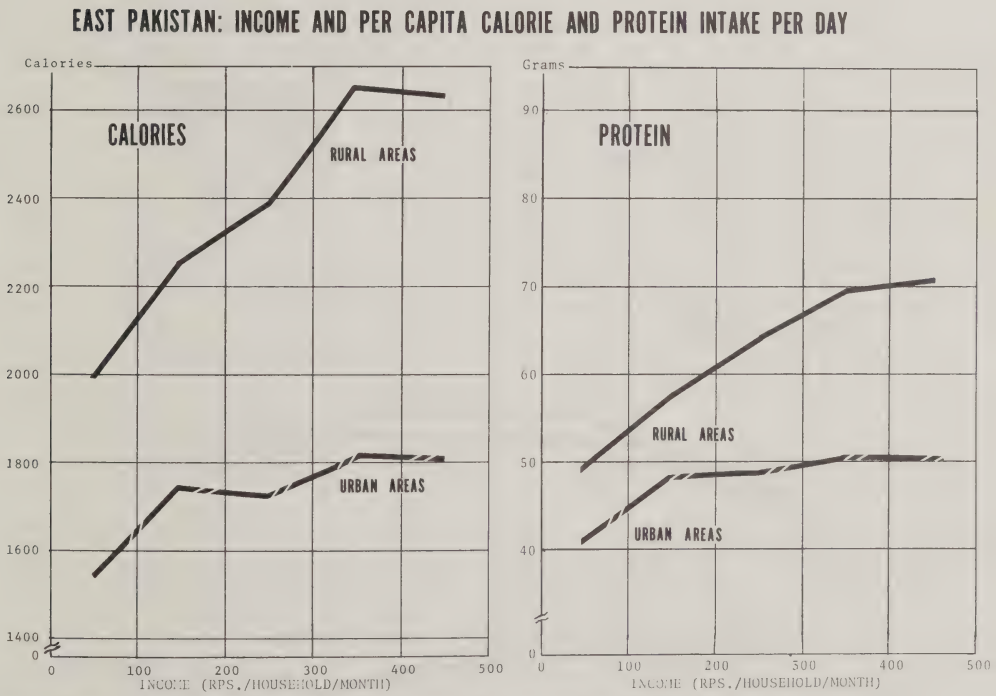
Berg correctly points to many foods which are considered foods of the poor, even though they are highly nutritious--quinua (a cereal) in the Bolivian altiplano; pute (steamed pudding with coconut) in Madras; and red rice and pulse leaves in East Pakistan. As incomes increase, these foods are often

Figure 2




SOURCE: Food Consumption in Brazil- 1960, Center for Statistical and Econometric Studies, February 1969.

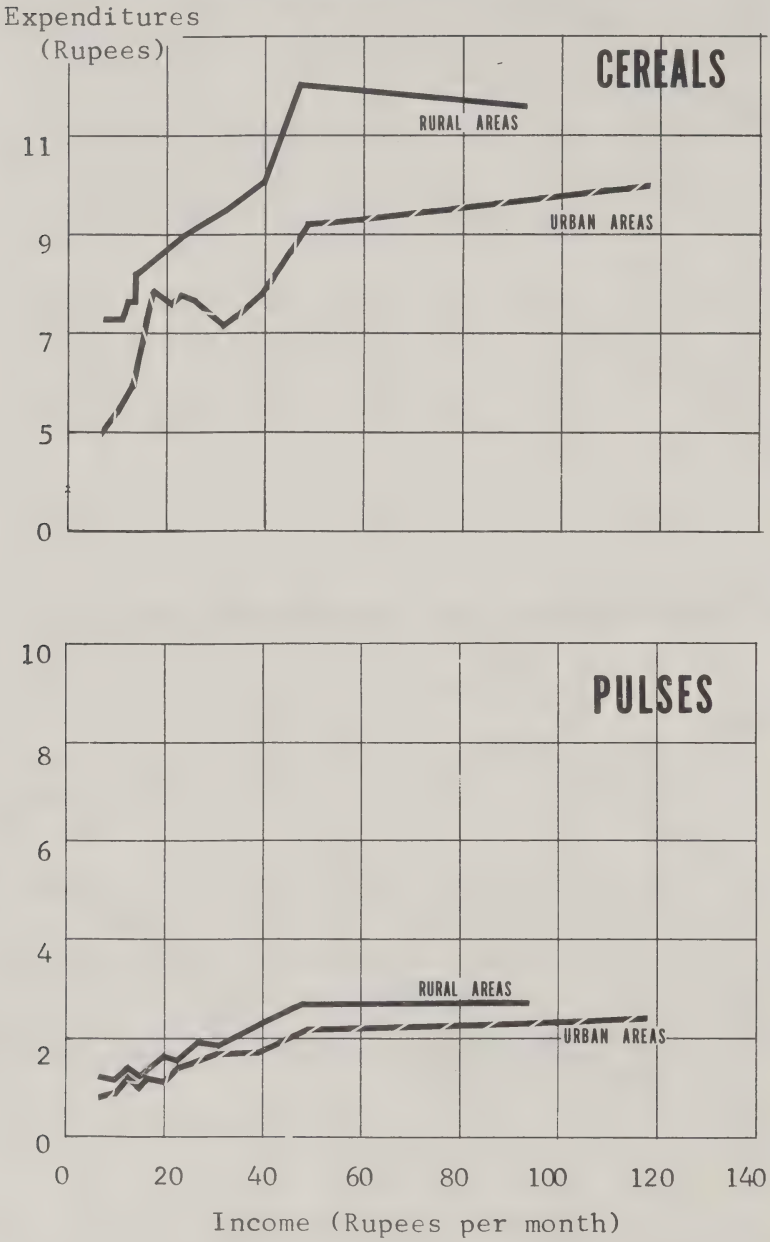
Figure 3



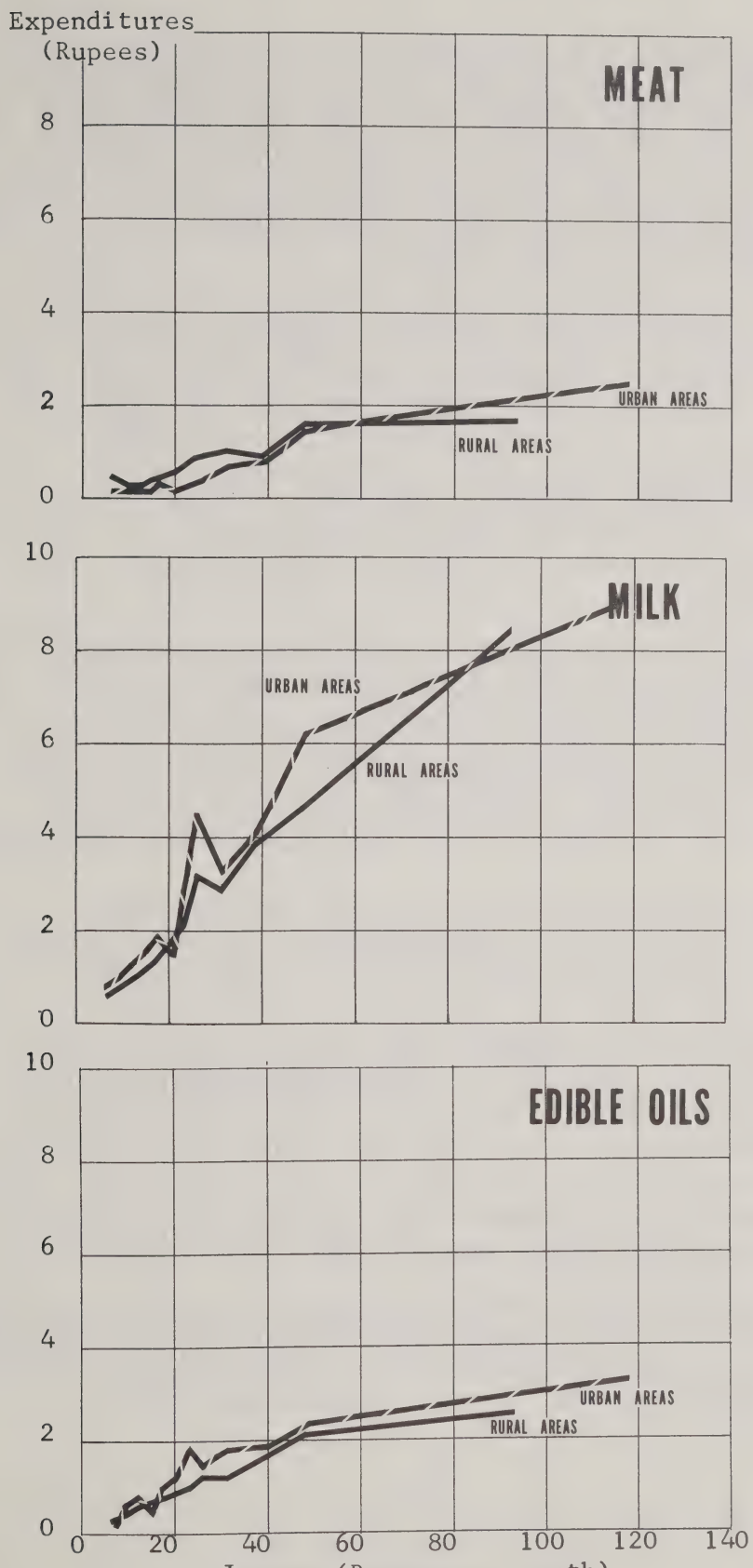

Source: Nutrition Survey of East Pakistan, March 1962--January 1964, Appendix Table II-11.

Figure 4

# INDIA: INCOME AND PER CAPITA EXPENDITURES PER MONTH, SELECTED COMMODITIES




Source: National Council of Applied Economic Research, All India Consumer Expenditure Survey, Vol. II (New Delhi, National Council of Applied Economic Research, 1967), Table 50.


Expenditures
(Rupees)
MEAT
8
6
4
2
0
URBAN AREAS
RURAL AREAS
10
8
6
4
2
0
MILK
URBAN AREAS
RURAL AREAS
10
8
6
4
2
0
EDIBLE OILS
URBAN AREAS
RURAL AREAS
0
20
40
60
80
100
120
140
Income (Rupees per month)

replaced with less nutritious food.1/ Urbanization can also have an influence on the quality of the diet. Jelliffe and Jelliffe point forcefully to a decline in breast feeding among people migrating to cities in the developing countries and the merchandising of high priced "unaffordable and inappropriate" infant foods.2/

The negative effects of income growth on nutrition to which Berg refers are tremendously difficult to change. My personal guess would be that their magnitude, while significant, is more than offset by the positive effects of income growth, even at low income levels. Quantitative data appear lacking, however. And food surveys usually use constant nutrient coefficients without adjustments for these variations among income groups.

The fact that income is a primary explanation for changes in nutrition suggests that nutritional improvement will not be accomplished quickly. In fact, the opposite is the case. Outlook for income growth is such that great dependence will continue on staple foods, which means that protein deficiences in terms of quality and quantity will continue for many years.3/

Patrick Francois demonstrated that the potential effect of income in relieving protein deficiencies is slower than usually realized. For example, for a

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1/ Alan Berg, Increased Income and Improved Nutrition: A Shibboleth Examined, in The Marketing Challenge, ed. by Martin Kriesberg (Washington, D.C.: Foreign Economic Development, U.S. Department of Agriculture, 1970), pp. 41-45.

2/ Derrick B. Jelliffe and E. F. Patrice Jelliffe, "The Urban Avalanche and Child Nutrition," Journal of the American Dietetic Association, August, 1970.

3/ M. Autret and J. Perisse, "Indicative World Plan for Agricultural Development: Nutritional Digest," Nutrition Newsletter, Food and Agriculture Organization of the United Nations, Vol. 8, No. 2, April-June, 1970.

selected country, growth in per capita real income over a 13-year period of 1.7 percent per year was assumed. This meant that per capita rural incomes would increase only from $52 to $65. In turn, per capita protein consumption would increase less than 5 percent. Animal protein would increase 23 percent, but less than 2 grams in the 13-year period. Additional calculations by Francois for the same country showed that, in 23 years, income can reduce the number of people "...whose protein status is unsatisfactory by only half," although in this case, due to increases in total population, the percentage of the population with deficient diets dropped from 50 to 16 percent.1/

Thus, a partial closing of the protein gap is in prospect, but for most lower income countries, this gap will not be closed for many years.

The IWP estimates suggest that India could close its protein gap by one-third in the years between 1962 and 1975, and another one-third in the following decade.2/ The IWP studies also lead FAO to conclude that in 1975 eleven countries with 63 million people south of the Sahara will still have a protein gap. As of 1985, there will be nine countries in this area with 68 million people still facing this problem.

These calculations, of course, depend substantially on the definition of self-sufficiency, rates of economic growth, and the impact of this growth on income distribution. But under any reasonable set of assumptions, the closing of the protein gap for many of these poorer countries is a long way off.

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1/ Patrick J. Francois, "Effects of Income Projection on the Protein Structure of the Diet," Nutrition Newsletter, Food and Agriculture Organization of the United Nations, Vol. 7, No. 4, Oct.-Dec., 1969, p. 12.

2/ Food and Agriculture Organization of the United Nations, Lives in Peril: Protein and the Child (FAO, 1970), p. 41.

## IV. THE WHIPLASH EFFECT ON THE POOR

Economic growth can improve national nutrition averages but, at the same time, make the low income people worse off. One reason for this potential whiplash on the poor is that, as people's incomes rise, they desire more animal products and bid grain away from the bowls of the poor for use as livestock feed. These prospective developments suggest the need for continued attention to programs which provide food to low income groups.

The IWP estimates that demand for livestock and livestock products will increase sharply. For the developing countries as a whole, it projects demand for livestock products growing 4 to 5 percent per year. In contrast, the supply of livestock at current prices is expected to increase 2.9 to 3.8 percent per year, thus giving rise to a substantial gap of animal source protein. This gap is estimated at 10 percent of supply by 1975 and over 30 percent by 1985. The imbalance for milk products alone would total 34 million tons, roughly 40 percent of projected production in the LDC's.

Table 3--Developing countries 1/: Protein from animal sources, 1962 and projected for 1975 and 1985.

| | 1962 | 1975 | 1985 |
|---|---|---|---|
| | ----------Million Tons---------- | | |
| Demand | 5.5 | 9.5 | 15.2 |
| Supply | 5.5 | 8.6 | 11.6 |
| | | .9 | 3.6 |

1/ IWP Zone C Countries

Source: Based on data of M. Autret and J. Perisse, "Indicative World Plan for Agricultural Development," Nutrition Newsletter, Vol. 8, No. 2, April-June 1970, FAO, Table 1, p. 12.

These developments are likely to make a positive contribution to overall average nutrition of these countries. But, these benefits will be largely concentrated with the higher income groups, and lower income groups could find themselves worse off as changes in prices occur in order to close the gap between the quantity demanded and the quantity supplied.

The whiplash effect on the poor could come about as follows:

- Increased demand for livestock products leading to increased livestock product prices.

- These higher livestock product prices in turn meaning increased demand for cereals for food. This could be met by larger cereal imports, decreased exports, or higher cereal prices.

- Assuming no changes in trade, the higher cereal prices would have a double effect: (1) stimulate increased production of cereals, and (2) restrain consumption of cereals as food.

- The conversion of the cereals into livestock products will largely mean an improvement in the diets of the higher income people and the incidence of the decreased cereal consumption as food will fall heaviest on low income groups with diets already inadequate in calorie and protein content.

Estimation of the related parameters is extremely limited. In a dynamic setting, these developments may slow the expansion of consumption of cereals as food more than would otherwise occur if cereals were not being used as feed.

The situation whereby the low income countries sell large amounts of protein to developed countries for feed while their populations have severe protein

deficiencies illustrates the working of economic demand and supply in a manner similar to that suggested above. Peru, for example, exports large amounts of fish and fish products, yet the per capita protein intake of the people of Peru is only 58 grams per day. In these cases, the lower income people, in spite of their inadequate diets, simply do not have the effective demand to compete with the incomes of the people of the United States and Europe who demand livestock products which can be produced with these high protein products of the low income countries.

A parallel situation has been the export of U.S. food products on a concessional basis, while portions of our own population were inadequately fed.

There are even more poignant reminders that people with high incomes can attract food away from people with low incomes even if their diets are inadequate. For example, an orphanage in Korea found it advantageous to sell the milk produced by a dairy cow given to them under a U.S. program rather than feeding it to the orphans. The money received in the market for the milk was simply more valuable to the orphanage than the milk itself, even though it could have made an important contribution to the quality of the orphans' diets.

The dilemma is brought into focus by considering the alternative policies which might be taken for its resolution. One policy approach is to stifle the consumption of animal protein through high livestock prices. But such a policy, unless combined with a high cereal price policy, leads to lucrative profits in livestock production. This situation, in turn, is likely to mean substantial demands for cereals and higher cereal prices anyway, with consequent effects on nutrition.

Alternatively, a low livestock price policy would stifle the effect of the increased demand on grain prices. But, low livestock prices would mean larger

quantities of livestock products demanded and probably heavy foreign exchange requirements to meet the demand.

Another alternative is to somehow isolate the feed and the food markets and promote high prices of cereal for feed but lower prices for food.

Regardless of the particular policy approach for livestock prices, these prospective developments suggest the need for continued attention to programs which provide food to vulnerable low income groups. It is through such programs that the poorest might be somewhat insulated from possible adverse whiplash effects of income growth.

## V. COSTS AND WHO PAYS

Cereal breeders have demonstrated that the balance of amino acids and the protein content of cereals can be improved through selection and other breeding techniques. We also know that, through fortification, the amount of utilizable protein available from cereals can be increased by adding other sources of protein or specific amino acids to the cereals. Because there is limited potential for increased incomes to solve the protein problem, these two considerations of supply--cereal breeding and fortification--take on increased urgency.

The potential for breeding and fortification programs, however, rests with their ability to make improved nutrition available at lower prices than traditional approaches, thereby enhancing the real value of the limited incomes in these countries. In this way, breeding and fortification programs could potentially let lower income countries enjoy levels of nutrition above those of Europe and America at comparable income levels.

Three of the more obvious questions about cereal breeding and fortification programs are: Who pays? Who benefits? By how much?

Costs are of two types: (1) development, and (2) implementation.

### Development Costs

Significant funds are being devoted to the breeding of cereals with higher quality and quantity of protein. For the most part, these funds are government and foundation funds. A very large proportion of them are U. S. monies through the U. S. Department of Agriculture, the Agency for International Development, and U. S. foundations and universities. But,

in addition, some U.S. private companies are doing work, especially adaptive type research.

In contrast, there has been little support for food legume improvement, even though it has long been recognized that these crops occupy a strategic role in diet improvement.

What about the developmental costs of fortification material? My observations suggest almost the opposite to the improved variety situation. Government funds do not significantly support major research on the synthesis of amino acids, even though the costs of tryptophan and threonine remain important barriers to their use in fortifying cereals. In contrast, selected private companies appear to be financing this research work.

The situation seems mixed with respect to high protein supplements. Aaron Altschul and his colleagues at the USDA Southern Utilization Research Division pioneered, in cooperation with many cottonseed processors, the development of highly nutritious cottonseed flour. The USDA Northern Utilization Research and Development Division carried out intensive work on soy flour. At the same time, several private companies have made great advances in this technology.

Is there not an important potential contribution government could make by funding research on synthesizing amino acids? Lysine is relatively low in cost. But what about threonine and tryptophan? 1/

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1/ Current prices for amino acids per pound of material are:

| | |
|---|---|
| L - lysine | $1.00 |
| L - threonine | $7.50 |
| DL - Tryptophan | $5.90 |

Rosenfield estimates that these prices would translate into the following costs per metric ton of cereal of

The need for more research goes beyond basic research. Do we know enough about fortifying rice with amino acids so that the added nutrients will not be lost when cooked with large amounts of water? What is the stability of lysine introduced in a wheat mixture before grinding into atta?

Private companies will work in these areas. But, are the risks sufficiently small so that private companies will devote substantial resources to this type of research? And, will they ask the same questions, disclose the same information, and do it as quickly as it needs to be done?

(con'd)
fortifying with needed amino acids, as well as vitamins and minerals:

| | |
|---|---|
| Yellow corn | $20.06 |
| Rice | $22.48 |
| Wheat Flour | $ 5.29 |

(Daniel Rosenfield, "Current Amino Acid Fortification Programs," Proceedings of International Conference on Fortification (MIT Press, Forthcoming).)

Various writers suggest that these costs, especially for threonine and tryptophan, will decline substantially. Rosenfield anticipates a price of $3.00 per pound for L-threonine, which would translate into a rice fortification cost of $12.78 per ton of rice instead of $22.48. But, hard information is extremely scarce on either economies of scale using current technology or magnitudes of research endeavors and, in turn, prospective lowering of costs. This shouldn't be too surprising, perhaps, when even current prices and industry capacity are at best obscure. But, it does raise serious questions regarding the advisability of designing protein strategies based on sharply lower material costs without investing modest government funds to better assure that these lower costs will be realized.

Most agree that society, through government research programs, should pay for a substantial portion of basic and applied agricultural research. This consensus is based on the atomistic nature (many small producers) of agriculture and the potential distribution of the benefits from such research.

Returns to society from agricultural research have been large and widespread. 1/ While benefit-cost ratios are high for society as a whole, for an individual farm producer the private costs may be greatly in excess of the potential return to him, simply because he is such a small part of society.

Private companies primarily conduct research when the anticipated benefits to them are greater than their costs. To do otherwise would lead to bankruptcy. These companies have traditionally done a

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1/ See for example (1) Z. Griliches, "Research Costs and Social Returns: Hybrid Corn and Related Innovations," Journal Political Economy, Vol. 66, Oct. 1958, pp. 414-31, which estimated a net social rate of return for agricultural research of 35 to 170 percent; (2) Zvi Griliches, "Research Expenditures, Education, and the Aggregate Agricultural Production Function," American Economic Review, Vol. LIV, No. 6, Dec. 1964, pp. 961-74, which estimated a "gross social rate of return to R&E expenditures" in agriculture of about 300 percent; (3) Willis L. Peterson, "Return to Poultry Research in the United States," Journal Farm Economics, Vol. 49, No. 3, Aug. 1967, pp. 656-69, which concluded that investment in poultry research has been yielding a return of about 20 to 30 percent per year from the date of investment; and (4) R. E. Evenson, J. P. Houck, Jr., V. W. Ruttan, "Technical Change and Agricultural Trade: Three Examples-Sugarcane, Bananas, and Rice," Minneapolis, University of Minnesota, December 1968, Mimeo, which discusses the role of research in development of selected tropical crops.

large share of the research on farm chemicals and farm machinery, but less in other lines.

Arguments parallel to those justifying government support of agricultural research can be made to justify government support of the development of fortification techniques and new foods. These arguments stem from the demand side rather than the viewpoint of producers. Consumers are atomistic and, therefore, while individuals as a whole may benefit greatly from an improved food, the prospective benefit to any one individual would likely be very small in comparison to the development costs. Thus, consumers do not finance substantial research in this area.

Again, private industry carries out that research for which they can make a profit. Undoubtedly, much of it coincides with the interests of consumers. But there are likely many research projects that would benefit consumers that are not justifiable to an individual company and thus are being studied insufficiently or not at all. Is the synthesis of amino acids one of these areas?

Implementation Costs

The carrying of implementation costs is almost opposite that of development work. The use of government funds to subsidize farm production of high protein varieties and their use by consumers is limited. In contrast, we often think of government funds being used extensively to implement fortification programs, at least for the initial efforts.

Improved Varieties

One great attraction of the variety improvement approach is the implicit anticipation that the product will compete with other farm crops in production

decisions of farmers, move through the normal market system, and be purchased by the consumers who need it.

This may all come to pass. But, it appears doubtful unless plant scientists develop high protein cereal varieties with yields higher than available low protein varieties.

Diet improvement is hampered because nutritious foods are not inherently more attractive nor are their effects immediately obvious to the skeptic. Both producers and consumers tend to emphasize quantity rather than nutritive value in making decisions.

Needed, perhaps, are policies and programs which would favor the production and use of high protein varieties. This would help combat the "quantity syndrome." Producers could be offered higher prices for high protein corn than for other corn. In turn, this corn could be resold at prices below the other corn in order to stimulate its use. These approaches, of course, might be designed especially to stimulate introduction of the varieties and then later adjusted to eliminate the advantages given to high protein varieties.

Unfortunately, quantity rather than nutritional value will continue to be the main criterion of producers as well as most consumers in these countries. For many years to come they cannot be expected to discard the quantity syndrome for sophistication in formulation employed by U.S. feed manufacturers. Quantity will remain an overriding consideration.

Fortification

We know that to satisfy nutritional requirements with traditional methods will require income levels many times present levels. The fortification approach is much lower in cost, but it is still expensive in terms of either low income countries' resources or the willingness of developed countries to provide aid. For

example, to fortify the 12 million ton of cereals consumed in East Pakistan would cost $150 million, equivalent to 25 percent of the Government of East Pakistan budget and 2.1 percent of the GDP of that province. 1/

The comparable estimates for India would be $1.2 billion total cost, which would be 16 percent of the central government budget and 2.5 percent of GDP. According to cost estimates reported by Kracht, soybean flour fortification would be about 50 percent higher. 2/ Thus, while the costs of fortification are vastly lower than accomplishing the same nutrition with traditional foods such as meat and livestock products, they are nonetheless substantial in terms of the resources of the low income countries.

However, the costs of several vitamins and minerals which are very deficient in many of the developing countries are extremely low. These cost levels, along with their known and accepted effects on health, cause one to ask why greater emphasis is not being given to mineral and vitamin fortification programs, especially in circumstances where it is not practical from a cost viewpoint to proceed with amino acid fortification. For example, materials for mineral and vitamin fortification would cost only $.75 per ton of rice or wheat.3/

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1/ These calculations are based on the prices given in Rosenfield, op cit. (using the $3 threonine price) and the amounts of fortification indicated in Daniel Rosenfield, Stanley Gershoff, and Lyle Schertz, "East Pakistan: Possibilities for Cereal Fortification," Foreign Economic Development Service, U. S. Department of Agriculture, March, 1970.

2/ U. Kracht, "Economic Aspects of the Supplementation of Cereals with Lysine," FAO/WHO/UNICEF/PAG, Ad Hoc Group on Amino-Acid Fortification (Mineo, 2 May 1969).

3/ Rosenfield, et. al., op. cit., pp. 12-14.

## Who Pays for Fortification?

Someone must pay for fortification programs, whether it be individual consumers, governments, or international assistance programs.

The willingness of an individual to pay for fortified products or high protein varieties depends on whether he thinks he is getting his money's worth. Unfortunately, especially in terms of fortification and plant breeding programs, history supports the idea that man places major emphasis on palatability rather than nutrition.

One of the great virtues of fortification is that traditional foods are not changed in appearance or taste. Inability to distinguish fortified flour from unfortified flour has merit in terms of fitting existing consumption patterns, for example. But, this virtue can also be a disadvantage in getting the consumer to pay a slightly higher price for a fortified product which is indistinguishable from an available unfortified product.

In several aspects, a nutrient cube that can be tossed in the cooking pot has considerable appeal. It has the potential of being a differentiated product acceptable to consumers as a carrier of improved nutrition. This approach also offers the opportunity of government subsidization gauged to the nutritional needs of the public and economic demand.

The development of pharmacies in East Pakistan which distribute large amounts of vaccines and medicines should be studied for possible lessons applicable to selling fortification. In spite of low income, the demand for modern vaccines and medicines is very evident; and the distribution system has developed amazingly in response to the demand. But for such things as vaccination for smallpox, the benefits may be very

dramatic and thereby contrast sharply in the peasant's mind with the benefits of nutrition. 1/

In a limited number of cases, private companies may find it advantageous to either (1) make fortified foods available to their workers, with the workers paying for the improved nutrition, or (2) pay for the improved nutrition directly, with the expectation that the costs are more than offset by the increased productivity of the workers.

In some circumstances, it may be possible to preempt the choice of consumers and thereby get them to pay the costs. For instance, governments might require that all flour be fortified. But, one must be careful not to be deceived as to how much progress such an approach really means in the context of the marketing systems and consumption patterns of the developing countries. For example, fortification programs of flour and atta were hailed by the Government of India as tremendous steps forward. They were especially important in introducing the concept of fortification. But, in terms of the cereal consumption of India, only a small proportion can possibly be involved in the near future. For example, if all flour and atta milled in commercial size plants were in fact fortified, only 11 percent of India's wheat consumption

1/ In all this, we must recognize the sharp discounting of deferred benefits. For example, the salability of improved nutrition is affected by the fact that the benefit may not be apparent for a considerable time afterward. Thus, selling improved nutrition may run counter to the "impulse gratification" pattern described by Rogers. [Everett M. Rogers, "Motivation, Values, and Attitudes of Subsistence Farmers: Toward a Subculture of Peasantry," in The Subsistence Farmer, Agrarian Cultures, and Peasant Societies, ed. by Clifton R. Wharton, Jr. (Chicago: Aldine Publishing Co., 1969)]

would be involved, which would be 2.5 percent of its cereal consumption and only 2 percent of its total food grain consumption. The percentages are admittedly increasing. But, in terms of India's nutrition needs, they remain extremely small.

In East Pakistan, only 10 to 20 percent of the rice produced enters what we would consider to be marketing channels. 1/ And, most of this is beyond the influence of a program requiring fortification.

Thus, the low income countries should consider the potential for preempting the choices of consumers, but they should not be overly optimistic as to the effect of this approach.

In the final analysis, governments in low income countries will likely need to consider carrying the costs of fortification. Therefore, approaches will be needed which direct fortified cereals to the vulnerable target groups. The fewer that receive the improved foods that do not need these foods, the lower real costs to society in reaching those that do need better nutrition. Some countries already have programs specially designed to make food available to lower income people. For example, several countries have school lunch programs. Others have ration shops and fair price shops which are designed to provide food for lower income, disadvantaged groups of people.

In several respects, these programs are consistent with Dalrymple's concept of price discrimination, i.e., market arrangements designed so that different consumers pay different prices for nutritionally the same product or, in some cases, the identical product.2/ These approaches, however, require an effective "separation" of markets so that products cannot be purchased in the lower-priced market and sold in the higher-priced market.

1/ Rosenfield, et al., op. cit.

2/ Dana G. Dalrymple, Economic Aspects of Nutrition Improvement in Tunisia (Washington, D. C.: U.S. Department of Agriculture, July 1970).

Depending on the particular prices selected, government subsidies might or might not be involved.

Along with special institutional arrangements to make food available to lower income people and government programs subsidizing the costs of fortification material, the role of international assistance in financing fortification programs needs to be examined. Practically all of the limited amounts of amino acids being used in low income country programs have been financed by international assistance. Hopefully this support will be maintained. Might it be expanded?

Consideration needs to be given to alternative techniques whereby fortification programs can be financed. For example, large amounts of cereals still move to the developing countries on concessional terms. Some of these cereals go to people with adequate diets, but significant amounts go to low income people with inadequate diets. This is especially true in particular programs. For example, in East Pakistan, the imported Japanese rice and the U.S. PL-480 wheat largely supply the food ration shops scattered throughout the country. Given the cereal protein, vitamin, and mineral deficiencies of East Pakistan, shouldn't Japan be sending fortified rice to East Pakistan? And shouldn't the United States be sending fortified wheat?

Dried milk provided under U.S. food assistance has been fortified with Vitamin A after finding the consumption of the unfortified product by some children suffering from Vitamin A deficiencies affected their sight. How greatly different is the situation where East Pakistanis eating Japanese rice and U.S. wheat suffer from iron, Vitamin A, and protein deficiencies? For the U.S. commodities, PL-480 funds might be used, but why not AID funds also?

# VI. THE PAYOFFS

We all agree that there is little question about the merits of adequate nutrition. In many respects, the benefits are self-evident, as they are for better education, housing, and clothing. But, in a larger sense, do we agree that nutrition is a priority area? Resources are scarce. There are not enough resources to do all things well--nutrition, education, housing, clothing.

The United States can more readily afford to establish a goal of adequate nutrition without knowing the economic benefits. Resources are more abundant. The tradeoffs are in terms of guns, bullets, and farm subsidies. In the U.S. context, it really does not matter all that much if improved nutrition brought about by the food programs leads to merely greater consumption, or if it means increased productivity of a human resource and a saving of social expenditures in terms of medical facilities and the like--in short an investment.

The case in the lower income countries is greatly different, however, because of more limited resource availability. Programs require a much higher benefit-cost ratio to earn consideration. Problems in fulfilling goals for education in many of the countries are instructive for those of us working in nutrition. Many low income countries imitated the United States in establishing goals of education for all children. But, resources are simply not adequate to meet these goals in many countries. And, in turn, these objectives are being scaled down drastically.

In the final analysis, the true indication of the priority placed on nutrition will be the allocation of resources to this problem relative to the resources devoted to other problems. But, for realistic decisions to be made, we need to know what contribution nutrition improvement can make to the important goals of economic growth and greater participation in the benefits of this growth.

Can we say that improved nutrition will move a population from widespread lethargy to greater productivity? Or are the benefits more modest? Do we know?

In many cases we simply do not know the payoffs from nutrition, especially in terms of the contribution of improved quality and quantity of protein.

Even though nutrition has great relevance to economics, the economics profession has given it practically no attention. The principal economic works have largely ignored human nutrition. More recently there has been interest in quality of labor, but largely from the view point of the effect of education.1/

Effective work on the economics of protein will require more sharply-focused nutrition research. Measurements of height, weight, skinfold thickness, serum albumen levels, and nitrogen retention are simply not sufficient for calculations of the economic dimensions of protein programs. Other measurements are essential but generally not available. H. B. Young, for example, suggests that "there have been relatively few studies relating status of malnutrition with physical performance." 2/

Is it possible to demonstrate that protein improvment programs improve physical and mental performance and reduce morbidity and mortality? Research on these kind of questions is needed. And then, closer linkages among nutritionists and economists must somehow be made in order that this research yields information that can be utilized in effectively measuring the economic dimensions of these activities.

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1/ Donald E. Scott, "Nutrition and Economics, A Preliminary Study," (Unpublished Ph.D. thesis, Harvard University, March 1970).
2/ H. B. Young,"Effects of Nutrition in Growth and Performance," Agricultural Science Review, CSRS, U.S. Department of Agriculture, Vol. 8, No. 2 and 3, 1970.

# VII. SUMMARY

Two thirds of the world--the poor countries--command only one half of the world's protein, a large part being low biological value cereal protein. Looking at this world protein problem another way, the billion people of the developed countries use practically as much cereals as feed to produce animal protein as the two billion people of the lower income countries use directly as food.

Plant breeding and cereal fortification programs designed to cope with this problem must take into account the great variability in the protein content of diets. There is variation not only among nations and regions but even among members of families. This situation argues for a wide range of programs and great flexibility in the design of specific programs.

The outlook for income growth is such that great dependence on staple foods will continue; in turn, protein deficiencies in terms of quality and quantity will persist. This is the basic reason, barring a miracle, why nutrition improvement must be viewed as a long-term process.

Also, economic growth has the potential to make the low-income people worse off nutritionally, even though national averages improve. Prospective gaps between demand and supply for animal protein at unchanged prices will lead to higher prices for animal products. These prices in turn will attract resources from low-income groups.

Because of the limited potential for increased incomes to solve the protein problem, considerations of supply--cereal breeding and fortification--take on increased urgency. One of the important aspects of cereal breeding and fortification programs is that they make improved nutrition available at prices lower than are possible through traditional approaches.

The most obvious questions about fortification and high protein variety programs are who pays and who benefits--and by how much?

Costs can be thought of as being two types--development and implementation. Substantial government funds are supporting the development of high protein cereal varieties. However, little money is spent on food legume improvement, even though these crops occupy a strategic role in diet improvement. Also, government funds are not supporting major research on the synthesis of amino acids. Yet, costs of tryptophan and threonine remain significant barriers to their use in fortifying cereals.

One of the great attractions of the cereal breeding approach is the implicit anticipation that the product will compete with other crops in production decisions of farmers, move through the typical marketing system, and consumers who need the product will buy and utilize it in place of other foods. This may all come to pass. But, it appears doubtful unless plant scientists develop high-protein cereal varieties with yields higher than available lower protein varieties.

While the costs of implementing amino acid fortification programs are substantial, they are vastly lower than reaching the same nutrition level with traditional foods such as meat and livestock products. Also, the cost of several vitamins and minerals, which are deficient in many developing countries, is extremely low. These cost levels, along with their known and accepted effects on health, cause one to ask, "Why isn't greater emphasis being given to mineral and vitamin fortification programs, even in circumstances where it is not practical from a cost viewpoint to proceed with amino acid fortification?"

Implementation of fortification programs confront questions as to who should bear the costs--individual consumers, governments, or international assistance programs? Attention should also be given to the potential role of international assistance in providing fortified commodities.

One of the great virtues of fortification is that the traditional foods are not changed in appearance or taste. But, this virtue can also be a disadvantage in terms of getting the consumer to perceive a benefit and in turn pay a slightly higher price for the fortified product which is undistinguishable from the unfortified.

Opportunities to preempt the choice by consumers, such as requiring all flour to be fortified, should not be overlooked. But, the limited impact of such programs on the large number of subsistence people in these economies should be recognized. Price discrimination and special arrangements such as school lunch programs represent important opportunities for governments to increasingly reach selected target groups, even when it is not feasible to carry out a widespread fortification program.

Resources are scarce. There are not enough resources to do all things well and choices need to be made. To make these choices wisely, however, requires knowledge of the economic payoffs of improved protein nutrition. But, effective work on the economics of protein will require more sharply-focused nutrition research. We simply do not know the contribution of improved quality and quantity of protein to physical and mental performance. And then, too, closer linkages among nutritionists and economists are needed. Failure to effectively measure the economic dimensions of nutrition programs runs the risk that decision makers will bypass protein programs for others. And, no one will be able to show them that they have selected the wrong ones.

# VIII. APPENDIX

Appendix Table 1.--World: Total protein supplied by food groups, 1959-61 average.

| Subregion | Population 1959-61 | Wheat | Rice | Corn | Other cereals | Cereal total | Pulses & nuts | Animal | Other | Total protein |
|---|---|---|---|---|---|---|---|---|---|---|
| | - Million - | | | | | Million tons | | | | |
| DIET ADEQUATE COUNTRIES: 1/ | | | | | | | | | | |
| U.S. & Canada | 198 | 1.0 | nil | .2 | - | 1.2 | .3 | 4.6 | .5 | 6.6 |
| Mexico | 35 | .1 | nil | .4 | - | .5 | .2 | .2 | nil | .9 |
| Brazil & River Plate | 93 | .5 | .2 | .2 | - | .9 | .4 | 1.0 | .2 | 2.5 |
| N & S Europe | 308 | 2.8 | .1 | .1 | .3 | 3.2 | .4 | 4.9 | 1.0 | 9.6 |
| USSR & E Europe | 331 | 3.6 | .1 | .2 | 1.2 | 5.1 | .3 | 3.5 | 1.2 | 11.1 |
| Japan | 93 | .3 | .7 | - | .1 | 1.1 | .4 | .6 | .2 | 2.4 |
| Oceania | 13 | .1 | nil | nil | - | .1 | nil | .3 | nil | .5 |
| South Africa | 18 | .1 | nil | .2 | - | .3 | nil | .2 | nil | .5 |
| Subtotal | 1,089 | 8.6 | 1.1 | 1.2 | 1.6 | 12.4 | 1.9 | 15.4 | 3.2 | 33.0 |

-Continued-

Appendix Table 1 Continued--

| Subregion | Population 1959-61 | Wheat | Rice | Corn | Other cereals | Cereal total | Pulses & nuts | Animal | Other | Total protein |
|---|---|---|---|---|---|---|---|---|---|---|
| | - Million- | | | | -Million tons | | | | | |
| DIET DEFICIT COUNTRIES: | | | | | | | | | | |
| Other LA | 84 | .3 | .1 | .3 | nil | .7 | .2 | .6 | .2 | 1.7 |
| Other Africa | 242 | .6 | .2 | .8 | 1.1 | 2.8 | .7 | 1.0 | .9 | 5.3 |
| Communist Asia | 713 | 2.1 | 3.9 | 2.4 1/ | - | 8.4 | 1.8 | .8 | 1.4 | 12.4 |
| India | 432 | 1.2 | 2.0 | .4 | 1.4 | 5.0 | 2.3 | 1.1 | .4 | 8.8 |
| Other Asia | 452 | 1.8 | 2.7 | .5 | .2 | 5.2 | 1.0 | 1.5 | .8 | 8.6 |
| Subtotal | 1,923 | 6.1 | 8.9 | 4.4 | 2.8 | 22.1 | 6.0 | 5.0 | 3.6 | 36.7 |
| Total World | 3,012 | 14.6 | 10.0 | 5.5 | 4.4 | 34.5 | 7.9 | 20.5 | 6.9 | 69.8 |

1/ Including other grain.

Source: Derived from Table 2 - Quentin M. West - "The Quantitative Role of Cereals as Supplies of Dietary Protein" in "Protein: Enriched Cereal Foods for World Needs" by Max Milner.

Appendix Table 2---World:1/ Grain production 1960-1968.

| Area | 1960-64 average | 1967 | 1968 | CHANGE 1960-64 to 1968 | |
|---|---|---|---|---|---|
| | --Million metric tons-- | | | Tons | Percent2/ |
| TOTAL PRODUCTION: | | | | | |
| Developed Countries | 485 | 585 | 608 | +123 | +25 |
| Developing Countries | 283 | 325 | 335 | + 52 | +18 |
| Wheat | 45 | 51 | 59 | + 14 | +31 |
| Rice (paddy) | 138 | 155 | 156 | + 18 | +14 |
| Corn | 47 | 61 | 61 | + 15 | +32 |
| Other 3/ | 53 | 58 | 59 | + 6 | +10 |
| World | 768 | 911 | 943 | +175 | +23 |

1/ Excludes Communist Asia and Cuba.
2/ Calculated from unrounded numbers.
3/ Includes millet, sorghum, rye, barley, oats, and miscellaneous.

Source: Lyle Schertz, "Food Supplies and Economic Growth in Developing Countries in the 1970's," Western Agricultural Economics Association, Corvallis, Oregon, July 22, 1969.

Appendix Table 3--Selected regions: Utilization of agricultural products for food and feed, 1959-61 average.

| | Food | Non food use | Total |
|---|---|---|---|
| | -------Million metric tons------- | | |
| DIET ADEQUATE REGION: | | | |
| Wheat | 108 | 41 | 149 |
| Rice | 23 | 2 | 25 |
| Other Grains | 42 | 272 | 314 |
| All Grains | 173 | 315 | 488 |
| Other Starchy Crops | 116 | 159 | 275 |
| Pulses and Nuts | 10 | 5 | 15 |
| Milk Products | 152 | 128 | 280 |
| DIET DEFICIT REGION: | | | |
| Wheat | 61 | 11 | 72 |
| Rice | 194 | 15 | 209 |
| Other Grains | 83 | 28 | 111 |
| All Grains | 338 | 54 | 392 |
| Other Starchy Crops | 155 | 65 | 220 |
| Pulses and Nuts | 31 | 8 | 39 |
| Milk Products | 48 | 9 | 57 |

Source: The World Food Budget 1970, FAER No. 19, ERS, USDA, Table 36.

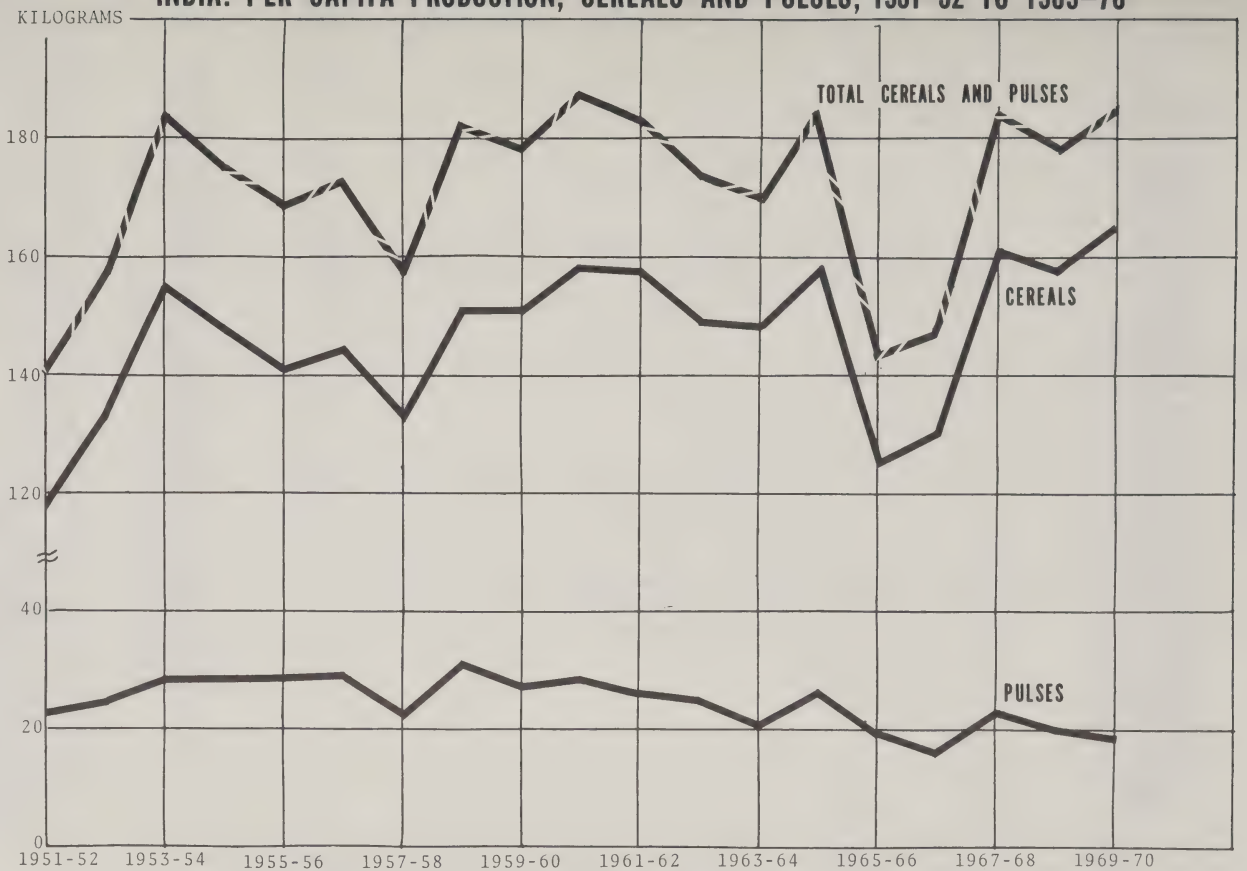
Appendix Table 4.--West Africa: Food consumption, 1965.

| | Savannah zone | South zone |
|---|---|---|
| Income per capita 1965 | 88 | 181 |
| Calories per day | 2189 | 2210 |
| Cereals kg per year | 167.6 | 83.8 |
| Starchy roots kg per year | 31.9 | 395.9 |
| Protein grams per day | 69 | 49 |
| Protein calorie ratio | 12.6 | 8.9 |
| Percent protein from animal sources | 18.3 | 16.8 |

Source: Agricultural Commodities-Projections for 1975 and 1985, FAO, Vol. I, p. 44 and Vol. II, pp. 192-3.

Appendix Figure 1

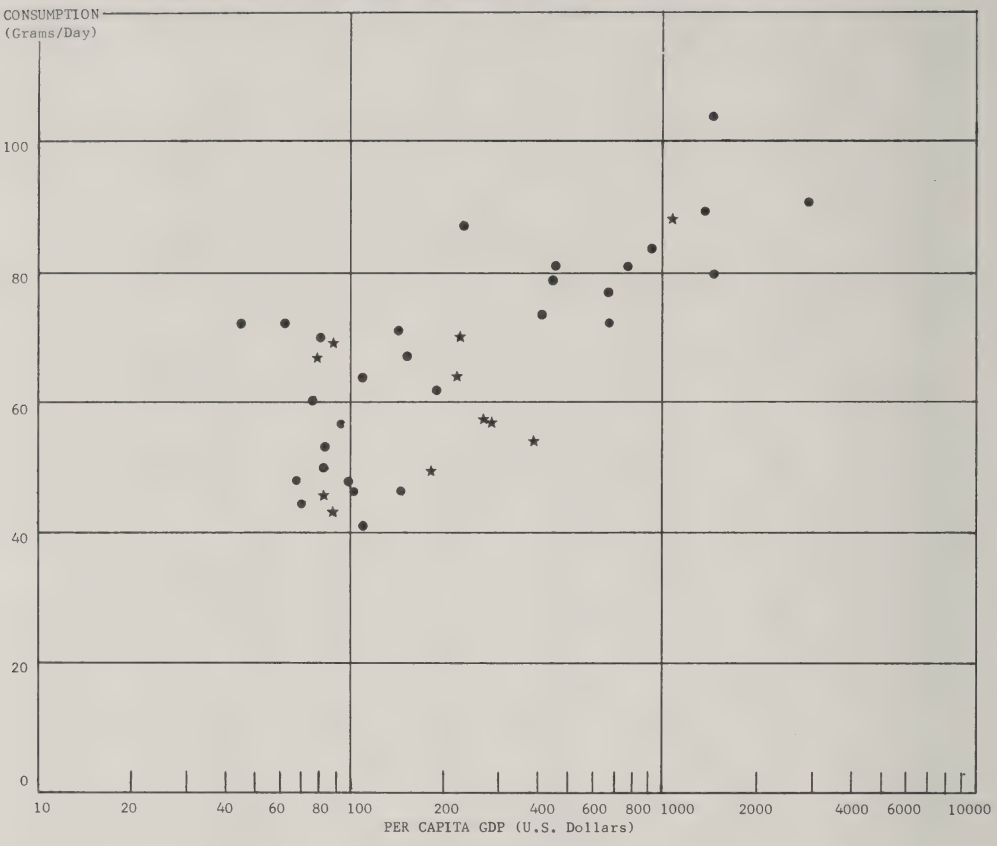
## INDIA: PER CAPITA PRODUCTION, CEREALS AND PULSES, 1951–52 TO 1969–70




SOURCE: "Brief on Indian Agriculture 1970," Office of the Agricultural Attache, American Embassy, New Delhi.

Appendix Figure 2

**SELECTED COUNTRIES: PER CAPITA CONSUMPTION OF PROTEIN AS RELATED TO PER CAPITA GROSS DOMESTIC PRODUCTION, 1965.**

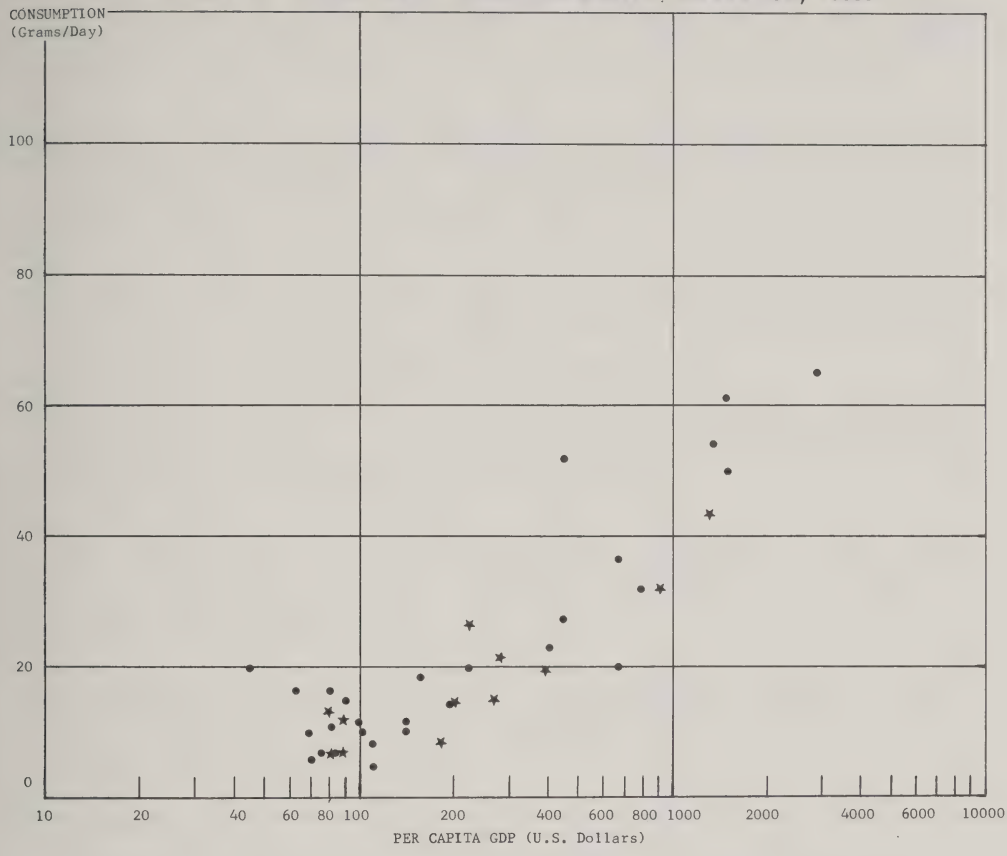



Source: Agricultural Commodities - Projections for 1975 and 1985, Vol II, FAO, 1967, Tables B and I.3.

Observations are plotted for all countries and groups of countries included in Table I.1, Vol II, Indicative World Plan, with 1965 populations greater than 20 million in developed countries and greater than 15 million in developing countries, except CAIS countries with 12.6 million and Kenya with 9.7. A ★ denotes group; ● denotes individual country.

Appendix Figure 3

**SELECTED COUNTRIES: PER CAPITA CONSUMPTION OF ANIMAL PROTEIN AS RELATED TO PER CAPITA GROSS DOMESTIC PRODUCTION, 1965.**

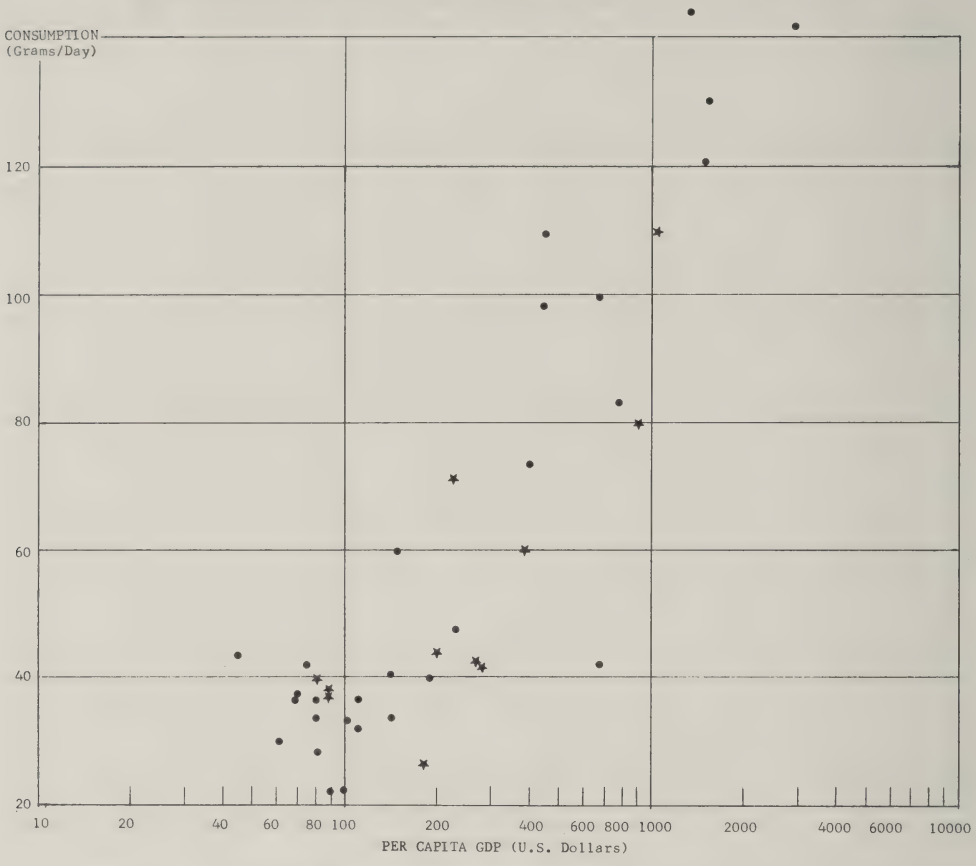



Source: Agricultural Commodities - Projections for 1975 and 1985, Vol II, FAO, 1967, Tables B and I.3.

Observations are plotted for all countries and groups of countries included in Table I.1, Vol II, Indicative World Plan, with 1965 populations greater than 20 million in developed countries and greater than 15 million in developing countries, except CAIS countries with 12.6 million and Kenya with 9.7. A ★ denotes group; ● denotes individual country.

Appendix Figure 4

## SELECTED COUNTRIES: PER CAPITA CONSUMPTION OF FATS AS RELATED TO PER CAPITA GROSS DOMESTIC PRODUCTION, 1965.




Source: Agricultural Commodities - Projections for 1975 and 1985, Vol II, FAO, 1967, Tables B and I.3.

Observations are plotted for all countries and groups of countries included in Table I.1, Vol II, Indicative World Plan, with 1965 populations greater than 20 million in developed countries and greater than 15 million in developing countries, except CAIS countries with 12.6 million and Kenya with 9.7. A ★ denotes group; ● denotes individual country.

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